

Workshop on bridging nonliving and living matter

Time: September 9-11, 2003

Location: Los Alamos and Santa Fe, New Mexico, USA.

Workshop organizers: Steen Rasmussen (LANL/SFI)¹, Liaohai Chen (ANL), David Deamer (UC Santa Cruz), David Krakauer (SFI), Peter Stadler (U of Vienna/SFI), and Norman Packard (Prediction Company/SFI).

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Background:

This workshop proposes to address the transition from nonliving matter to living matter through the formation of small, simple life forms that have essential properties of life. Several views regarding the construction of “minimal” life forms based on wet carbon chemistry have surfaced in recent years, but there has not been any international conferences or workshops on this subject. The time is ripe for a focused meeting that brings together the key players in this rapidly growing area and that helps establish a scientific community around the many technical problems associated with bridging nonliving and living matter.

There are two significantly different approaches to synthesize primitive life forms based on wet chemistry: A “bottom up” and a “top down” approach. The current workshop is focused on a bottom up approach concerned with constructing a simple living system from nonliving organic and inorganic materials through self-assembly, with metabolic processes driven by an external supply of free energy. The top-down approach concerns itself with systematic simplification of very simple existing cells.

We hope to be able to gather workshop participants from the Lipid World and the RNA World, including approaches with RNA-based cells as suggested by Luisi et al., Szostack et al., Deamer et al., and others. We also hope to be able to gather workshop participants to present the state of the art of the Peptide World as suggested by e.g. Ghaderi et al., as well as other approaches such as the integrated PNA/lipid aggregates suggested by Rasmussen and Chen.

We also hope to have a few participants from the top-down approach that takes the approach of constructing a minimal cell by “gutting” the DNA of one of the simplest existing cells, *Mycoplasma genitalium*.

Finally, the workshop will have perspectives on the key problem from a broader context of the scientific community, including (i) molecular self-assembly, (ii) synthetic chemistry, (iii) biologists studying contemporary primitive cellular life, (iv) energy scaling, (v) energy transduction in metabolic pathways, (vi) robustness, and (vii) the emergence of function from nanoscale form.

The goals of this workshop are:

- (I) To bring together for the first time a focused scientific team of experimentalists and theorists on the topic to assemble a simple proto-organism, both in vitro and in realistic (multi-level) simulations.
- (II) To identify problems and to develop consensus about possible processes that can bridge nonliving and living matter in a step-by-step, thermodynamically downhill manner.
- (III) To use this meeting as an initiation for a broader institutional collaboration with interest in Astrobiology, Artificial Life, Nanoscience (new materials), and related areas.

The proposed format:

The first day will be focused presentations on the different proposals for assembling proto-organisms bottom-up followed by short discussions (~45 min in all). Such presentations could include Szostack/Bartel, Luigi/Walde, Deamer/Pohorillo, Ellington (or somebody else from the RNA world), the Los Alamos Protocell (Chen/Rasmussen), and a few others. The first day is concluded by a presentation of the blueprint of the simplest known, modern unicell as well as a discussion of a modern virus. Thereby these extremely simple self-reproducing molecular systems are set into the context of contemporary biology. Claire Fraser or Hamilton Smith could e.g. be the last speaker of the first day discussing the usage of a top-down approach to simplify existing cells as much as possible, by eliminating non-essential genes. Ultimately (in many years) the bottom up and the top-down approach will meet.

Due to the general interest of the first day's talks they will be hosted at the Oppenheimer Center at Los Alamos National Laboratory, which can host about 150 persons including the workshop participants as well as interested scientist from the Los Alamos and Santa Fe communities. The following two days will be hosted at the Santa Fe Institute and is limited to the ~40 workshop participants.

The second day is devoted to short presentations (~15-20 min) on detailed technical (theoretical/computational and experimental) issues related to the different proposed proto-organism approaches. These short focused presentations are interleaved – or introduced - by more general talks (e.g. scaling, robustness, catalysis, information vs energy) that position the narrow technical presentations in a broader perspective. For example, we may pair a general talk on universal scaling relations in biology with a focused talk on the metabolic efficiency and effect of the proto-organisms. The protocells can thereby be placed near the “origo” in the general scaling diagrams. The workshop talks and discussions on the second day are partially structured around key themes such as energy vs information, robustness, fitness landscapes vs thermodynamics landscapes, catalysis, scaling, and complexity measures.

The workshop dinner (after the second day) could have a presentation on “Technological, ethical, and moral issues associated with the assembly of protocells.”

The last day (day 3, which is the most important part of the meeting, may continue with a set of short presentations in the morning, but a major focus will now be on discussing and scrutinizing the existing proto-organism design- and assembly approaches, identify problems, suggest solutions, and propose new avenues. This activity will occur in small groups followed by plenum discussions.

Proceedings:

We expect to develop a written (and an edited video) record of this meeting - or a review of the scientific activities in this emerging field provided by the participants. We propose to publish the papers in a special issue e.g. of the *Artificial Life* journal or similar journal as well as in a separate book e.g. MIT Press or Oxford University Press to ensure a wide distribution. Several journals and publishers have shown interest and the organizers are open for suggestions from the participants.

Confirmed participant list:

Mark Bedau, Reed, USA
Liaohai Chen (co-organizer) Argonne National Laboratory, USA
Stirling Colgate, LANL, USA
Shelly Copley, U of Colorado, Boulder, USA
Jim Crutzfield, SFI, USA
David Deamer (co-organizer) UC Santa Cruz, USA
Andy Ellington, U of T, Austin, USA
Doyne Farmer, SFI, USA
Walter Fontana, SFI, USA
Takashi Ikegama, U of Tokyo, Japan
Yi Jiang, LANL, USA
Dale Kaiser, Stanford, USA
David Krakauer (co-organizer) SFI, USA
Luigi Luisi, ETHZ, Switzerland
John McCaskill, Farunhofer, Germany
Harold Morowitz, George Mason U and SFI, USA
Peter Nielsen, U of Copenhagen, Denmark
Norman Packard (co-organizer) Prediction Company and SFI, USA
Andrew Pohorille, NASA Ames, USA
Kim Rasmussen, LANL, USA
Steen Rasmussen (organizer) LANL, USA
Andy Shreve, LANL, USA
Eric Smith, SFI, USA
Hamilton Smith, USA
Peter Stadler (co-organizer) U of Leipzig, Germany
Jack Szostak / Martin Hanczyc, Harvard, USA
Bryan Travis, LANL, USA
Jeff West, LANL, USA
David Whitten, QCL, USA
Woody Woodruff, LANL, USA

The organizers are welcoming suggestions for invited workshop participants. We prefer not to exceed ~40 workshop participants both due to the group dynamics, due to space limitations, and due to our limited budget. We would like to be able to pay travel expenses for the invited participants with our limited budget.
